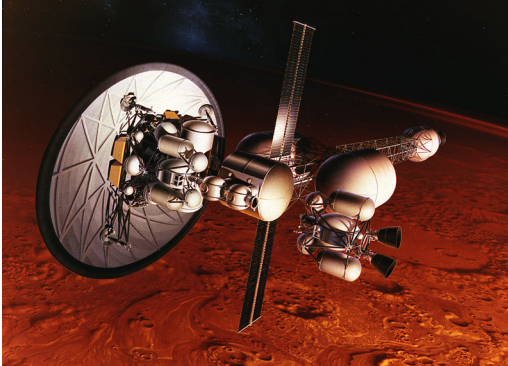


Propulsion Materials

Molybdenum-Rhenium Process Comparison

NASA Marshall Space Flight Center



Nuclear power and propulsion generation require materials that are stable at high temperatures, structurally sound, and compatible with diverse environments. No single material has been identified that is ideal for all applications: power generation equipment and supporting components needed for thermal management, shielding, controls, and structures. Multiple materials will have to be merged to transition from one environment to another within a single piece of hardware, usually from one side of a containment vessel to the other. Materials failures are often the result of bonding problems created by differences in the physical properties of materials that result in mechanical strain or metallurgical instability. Materials processing techniques that use graded transitions can reduce or eliminate these distinct bond lines that are usually the cause of failures.

Task Description

Investigators are comparing two materials application processes—diffusion bonding and plasma spray—that can bond or form layers of two refractory materials: molybdenum-40rhenium (Mo-Re) alloy and 100 percent rhenium (Re). These processes were selected

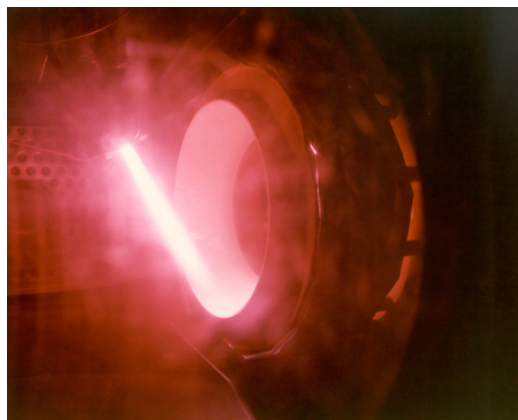
because they are flexible, scale up well to larger samples, and are documented in scientific literature. This allows the study to focus more on materials development and less on process development. Tasks include

1. Evaluating diffusion bonding and plasma spray uses in the scientific literature and for practical applications
2. Demonstrating two processes by bonding Re and Mo-Re
3. Comparing performance of these two bonding methods with traditional techniques such as welding and brazing.

This 2-year effort was initiated in FY05 and is being completed in FY06.

Anticipated Results

Rhenium and molybdenum were selected because of their potential for high-temperature applications, which makes them useful for rocket engine nozzles needed for high-temperature chemical fuels and nuclear fuels. The literature survey revealed the most common use of Re and Mo-Re is in small, uncooled thrusters, with some use in leading edge and heat pipe applications. Little information existed on bonding the materials, except for some electron beam welding analysis.



Materials failures can be the result of mechanical strain created when two materials do not bond well. Vacuum plasma spray may improve materials bonding. Here, a copper alloy is sprayed on a casting that replicates the throat section of the Space Shuttle Main Engine combustion chamber.

advanced materials for exploration

MOLYBDENUM-RHENIUM PROCESS COMPARISON

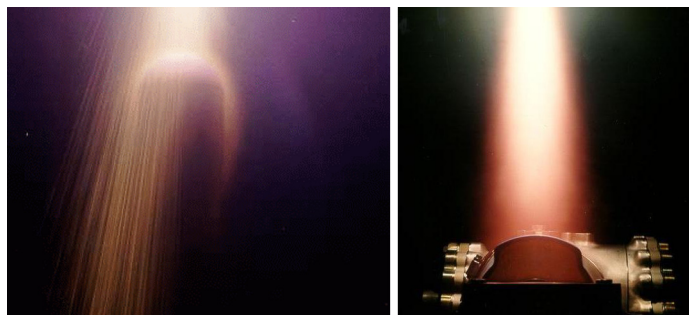
In FY05, investigators identified and evaluated methods (powder placement, foil, electroplate, thermal spray) for preparing the diffusion bond. As a precursor for evaluating the plasma spray method, they tested the method with tungsten, a less exotic refractory material. They prepared and analyzed the Re and Mo-Re samples and identified problems with the rhenium powder flow. In addition, the high energy required to spray these refractory alloys caused turntable overheating during the spraying process. Investigators are working to improve the flow by processing the powder, and they are adding shielding to isolate the turntable from samples during vacuum plasma spraying.

In FY06, investigators will continue to develop the plasma spray and diffusion bonding processes. At the end of this effort, investigators will have developed the application processes and compared results for the two materials. These results, along with the study of the technical literature, will provide a more complete set of data with which to select materials and their applications for propulsion components. The study will lay the groundwork for evaluating and comparing the many other candidate processes for forming gradient materials: chemical and physical vapor deposition, powder metallurgy, laser sintering, and other direct metal fabrication processes.

Potential Future Activities

The next steps are to refine processing, fabricate test specimens of each material, and conduct mechanical testing and failure analysis of the samples. The results of these more detailed studies would provide first-order mechanical properties, test data, and failure analysis, as well as more concrete data for design and trade studies examining materials needed for propulsion and nuclear power systems.

Marshall Space Flight Center (MSFC) has the facilities and expertise to perform this materials processing analysis and mechanical testing (up to ~1500 °F): plasma spray, hot isostatic pressing



Left: The Vacuum Plasma Spray system at NASA's Marshall Space Flight Center is used to spray tungsten on an 18-in. long graphite mandrel that forms part of a solar thermal absorber cavity.

Right: Copper is sprayed on a titanium fuel valve housing. A similar process will be used to bond layers of refractory materials: molybdenum-40rhenium and 100 percent rhenium. Plasma spraying will be compared to diffusion bonding of the same materials.

(HIP), metallography, electron microscopy, failure analysis, and mechanical testing in a variety of environmental conditions that simulate space flight and launch conditions. Experts in these processes, as well as welding, brazing, and electroplating, can develop processes and applications and compare them, providing meaningful trade studies and materials selection data.

Capability Readiness Level (CRL)

This Advanced Materials for Exploration (AME) task develops two materials processes applications and compares them (CRL 2). More extensive laboratory testing and materials evaluation would elevate this propulsion materials technology to CRL 3 and provide data for trade studies and materials selection criteria needed to amalgamate different refractory materials into propulsion components for thermal management, fuel containment, and fusion reaction applications.

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